

**California Energy Commission**  
**STAFF REPORT**

**FINAL EVALUATION REPORT**

**PROPOSED COMPLIANCE OPTION FOR:**  
**ALTHERMA AIR-TO-WATER SOURCE HEAT PUMP**  
**FOR THE RESIDENTIAL ENERGY**  
**EFFICIENCY STANDARDS**



CALIFORNIA  
ENERGY COMMISSION  
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## ABSTRACT

This final evaluation report presents findings and recommendations for Energy Commission approval of a compliance option for the Altherma Air-to-Water Source Heat Pump system. This system is manufactured by Daikin AC (Americas), Inc. The compliance option would establish the equipment efficiency ratings necessary to calculate performance of the Altherma system for showing compliance with the residential building energy performance path pursuant to the Building Energy Efficiency Standards (Standards).

The Altherma Air-to-Water Source Heat Pump can provide space heating and cooling and domestic water heating. Equipment used to show compliance with the Standards must meet federally mandated efficiency levels prescribed by the Department of Energy (DOE). However, the DOE has determined that current federal efficiency test procedures do not apply to the Altherma Air-to-Water Source Heat Pump. Hence, this system does not have efficiency descriptors to use for showing compliance with the Standards.

Staff solicited stakeholder comments and has conducted a public webinar to review the proposed draft efficiency ratings, which are included with the application for a compliance option. This report represents staff's response to public comment and its final recommendation for efficiency ratings to be used for the Altherma Air-to-Water Source Heat Pump system when showing compliance with the residential Standards.

Staff believes this request for a compliance option is warranted and recommends Energy Commission approval. The compliance option is comprised of the proposed efficiency ratings and installation criteria for the Altherma system that are specified in this Final Evaluation Report.

**Keywords:** California Energy Commission, Daikin, Altherma, air-to-water source heat pump, Building Energy Efficiency Standards, waiver from federal test procedures

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## Introduction

Daikin AC (Americas) has submitted an application and supporting information for a compliance option for use in demonstrating residential building energy compliance with the Building Energy Efficiency Standards (Standards). This application is to establish the equipment efficiency ratings that the Daikin Altherma Air-to-Water Source Heat Pump system would use when calculating energy compliance pursuant to the Standards. Proposed efficiency ratings would be used for the performance compliance approach for the Altherma system in newly constructed homes and additions to existing homes.

The Altherma Air-to-Water Source Heat Pump can provide space heating and cooling and domestic water heating. An exterior heat pump extracts heat from outside air, transferring the heat through refrigerant piping to a refrigerant-to-water heat exchanger, then uses the heated water for space heating (fan coil or radiant) and space cooling (fan coil or radiant), and water heating (domestic hot water via an indirect tank). Daikin is seeking approval of a compliance option for the Altherma Air-to-Water Source Heat Pump to change the current allowed efficiencies for the Altherma system to be based on European test procedures.

## Background

On June 23, 2010, the Energy Commission received an application and supporting information from Daikin AC (Americas) requesting approval of a compliance option for the Altherma Air-to-Water Source Heat Pump. Section 10-109 of the Standards allows for the introduction of new compliance approaches, which cannot be properly accounted for in the current approved compliance approaches. The Daikin application is the first step in the process to obtain Energy Commission approval of a compliance option, consistent with the compliance options procedures in Section 10-109.

Staff communicated receipt of the compliance option application and proposed two alternative approaches for Daikin to move forward. Staff also communicated the need for additional supporting information.

In a letter dated January 6, 2011, Daikin representatives notified Energy Commission staff that its preferred approach was staff's suggested "compliance modeling approach, Option A." This approach required determination of the efficiency descriptors to be used for the Altherma system when in space heating, space cooling, and water heating modes based on the DOE's authorization to use efficiency ratings for the system resulting from European test procedures. Daikin provided staff with necessary supporting information.

Energy Commission staff and representatives of Daikin met on March 15, 2011, to further clarify the dynamics of the operation of the Altherma system and its interface with calculated efficiency ratings from the DOE's authorized use of European equipment testing.

## Compliance Option

Space conditioning and water heating equipment used to show compliance with the Standards must meet federally mandated efficiency levels. However, the DOE has determined that current federal efficiency test procedures do not apply to the Altherma Air-to-Water Source Heat Pump. Hence, this system does not have efficiency descriptors to use for showing compliance with the Standards.

In 2009, the DOE granted Daikin an interim exception of the Altherma system from using the federal efficiency test procedures. Exceptions are given to appliances that have a design or function that cannot be measured using existing testing procedures. On June, 18, 2010, the DOE granted a waiver to Daikin from the existing DOE test procedure applicable to residential central air conditioners and heat pumps. The waiver applies to the Daikin Altherma air-to-water heat pump with integrated domestic water heating (Case No. CAC-024, 75 *Fed. Reg.* 117).

In early 2010, the Energy Commission posted on its website equipment efficiency listings for the Altherma systems to be used for showing compliance with the Standards. These efficiency listings are the minimum federal equipment levels for heat pumps:

- Space heating—HSPF 7.7
- Space Cooling—SEER 13
- Water heating—Energy Factor (EF) 0.904

Daikin is seeking approval of a compliance option for the Altherma Air-to-Water Source Heat Pump to change the current allowed efficiencies to be based on European test procedures.

- Daikin's request does not require modifications to performance computer modeling nor does it propose modifications to the prescriptive component packages
- Daikin's request does not require special calculations or enforcement checks that are different than those currently specified in compliance reference information
- Daikin's request does not change or modify compliance reference information used by the Standards, Reference Appendices, Residential Compliance Manual, or Compliance Forms

## Staff Evaluation

Staff reviewed the information provided by Daikin for the Altherma system based on European testing results. The data was for a limited number of test cases for a range of varying configurations of the Altherma system.

The Altherma system can be set up to operate in one or more multiple modes—space heating, space cooling, and water heating—and can be configured by the installer to meet varying needs using combinations of equipment having different operational parameters and with different control schemes. The system's design and installation are field adjusted and engineered dependent on the actual building, climate zone, and conditioning functions necessary for the

occupant's needs. In addition to being dependent on this field engineering, the energy use of the Altherma system is dependent on variations in the "balance of system" equipment that is not included in the limited test cases from the European testing or separately modeled within Energy Commission approved performance modeling procedures. Compliance modeling must be completed in advance of this field engineering and prior to when the specification of all the performance characteristics of "balance of system" equipment and controls are known.

In establishing compliance options, the Energy Commission takes care to achieve reliable energy savings results based on inspections that can be made by local building department staff or Home Energy Rating System (HERS) raters completing field verification. The Energy Commission endeavors to not overstate expected energy savings, particularly when variations in design, installation and configuration, which cannot be reliably demonstrated by building departments and HERS raters, can result in those savings not being achieved. In the case of the Altherma system, staff believes that the European test results provide a reasonable basis for a conservative estimate of the efficiency of the installed system, recognizing that field engineering may result in system enhancements that are not able to be addressed in energy performance software or to be inspected or verified.

Staff bases its conclusions on the European test results that are recognized by the DOE and that most closely represent the ambient and delivery temperatures used in performance modeling for equipment delivering the same end use services. Staff discussions with Daikin and documentation supporting the compliance option application reveal that the Altherma system can provide space heating either by functioning as a split system heat pump or as a combined hydronic system. Staff recommendations recognize that the system can be specified for compliance operating in either mode, and establishes efficiency levels for the system's operation in each of these modes.

Space conditioning equipment efficiency ratings are necessary for calculating energy performance used to show compliance with the Standards. In addition, the Standards require specific procedures for installers and third-party HERS raters to verify correct refrigerant charge and proper air conditioner system operation. These required installation procedures apply to split system air conditioners and heat pumps. In addition to proposed efficiency ratings for the Altherma Air-to-Water Source Heat Pump system, staff has included installation criteria required for this type of equipment. Installation requirements include: (1) installation and verification of controls to limit supplementary electric resistance heating, (2) verification of refrigerant charge, metering, or presence of a charge indicator display, and (3) verification of proper air system fan flow and air handler fan watt draw.

## **Public Review**

On November 30, 2011, a public webinar was held by Energy Commission staff to present the proposal representing the application from Daikin for approval of a compliance option. Staff presentation of the proposed compliance option focused on the efficiency ratings that would be allowed for use with the Altherma system and the installation criteria necessary to assure

performance reliability, consistent with the residential energy requirements for all heat pump systems.

In order for equipment to be used for compliance with the Standards specific equipment efficiency ratings must be used as input values to performance modeling software. Efficiency ratings for heat pumps are expressed as:

- Heating: Heating seasonal performance factor—HSPF. Note that for heat pump systems that do not have a tested HSPF value pursuant to federal test procedures, current compliance modeling rules allow this rating to be calculated based on the COP of the system using the following equation:  $HSPF = 3.2 \times COP - 2.4$ . Where: COP = coefficient of performance (Residential Alternative Calculation Method (ACM) Approval Manual, Equation R3-32)
- Cooling: Seasonal energy efficiency ratio—SEER. For systems that have received a waiver from federal SEER test procedures (but in so doing DOE has not banned the sale of the system in the U.S.), staff has assigned the SEER rating that is the minimum federal standards for that equipment
- Water heating: Energy Factor—EF

Based on the approaches previously established for the Standards, and considering data provided by Daikin from European test procedures, staff has proposed the following efficiencies be used for all models of the Daikin Altherma system:

<i>Space Heating</i>	HSPF—11 (split system heat pump) – calculated from Daikin COP data EF—2.4 (combined hydronic) – calculated from Daikin COP data
<i>Space Cooling</i>	SEER—13 – based on minimum federal SEER requirements
<i>Water Heating</i>	EF—2.4* - calculated from Daikin COP data

\*When a separate stand alone water heater is used to provide water heating, the EF for that separate water heater shall be used for performance standards compliance.

Information below responds to comments from interested parties:

1. *Provide a description of how the proposed efficiency ratings for the Altherma system were determined.*

The DOE granted Daikin a waiver from federal testing requirements for the Altherma system on June 18, 2010 (75 *Fed. Reg.* 117). The DOE decision allows Daikin’s Altherma system to be tested using alternate testing procedures of European Standard EN 14511 and rate the full load heating and cooling performance using coefficient of performance (COP) and energy efficiency ratio (EER).

Daikin proposed equipment efficiencies, based on data from European testing results, are shown in Table 1 below for nine models of its Altherma system.

**Table 1: Altherma European Test Results and Proposed Compliance Efficiency Ratings**

Description	Model No.	Capacity (tons)	Heating Mode		Cooling Mode		DHW
			Tested COP	Proposed HSPF	Tested EER	Proposed SEER	Proposed EF
Split Altherma LT	ERLQ036BAVJU	3	4.34	11.49	12.17	17.50	2.42
Split Altherma LT	ERLQ048BAVJU	4	4.24	11.17	9.95	16.53	2.53
Split Altherma LT	ERLQ054BAVJU	4.5	4.03	10.50	8.73	13.00	2.42
MonoBloc Altherma LT	EBLQ036BA6VJU	4	4.32	11.42	11.21	16.63	2.38
MonoBloc Altherma LT	EBLQ048BA6VJU	5	4.2	11.04	9.42	16.09	2.50
MonoBloc Altherma LT	EBLQ054BA6VJU	4.5	4.07	10.62	8.89	13.00	2.41
MonoBloc Altherma LT	EDLQ036BA6VJU	3	4.32	11.42	na	na	2.38
MonoBloc Altherma LT	EDLQ048BA6VJU	4	4.2	11.04	na	na	2.50
MonoBloc Altherma LT	EDLQ054BA6VJU	4.5	4.07	10.62	na	na	2.41

Source: Daikin letter to California Energy Commission dated, January 6, 2011.

**A. Space Heating**

Daikin has proposed efficiency ratings specific to each of the nine models of the Altherma system based on the results from the European test procedure. Consistent with the DOE waiver’s stipulation that COPs be used to characterize the Daikin Altherma system in space heating mode, and previously established Energy Commission approaches for determining HSPFs based on COPs when HSPF ratings are not available or authorized, Daikin proposed HSPFs from the tested COP values for each Altherma model.

COPs were derived from European testing conditions that are comparable to the conditions of the DOE testing procedures for the same equipment. Heating mode testing conditions for the European procedures and those of the DOE testing procedures are shown in Tables 2 and 3. The effective heat delivery of the air-to-water temperature for the Altherma system is derived from tested COPs having an outside ambient temperature of 44.6 F and indoor outlet temperature (i.e., leaving water temperature—LWT) of 95 F.

**Table 2: European Test Conditions—Heating Mode**

		Outdoor Heat Exchanger		Indoor Heat Exchanger	
		Inlet Dry Bulb (DB) Temp (°C / °F)	Inlet Wet Bulb (WB) (°C / °F)	Inlet Temp (°C / °F)	Outlet Temp (°C / °F)
Standard Rating Conditions	Outdoor air	7 / 44.6	6 / 42.8	40 / 104	45 / 113
	Exhaust air	20 / 68	12 / 53.6	40 / 104	45 / 113
	Outdoor air (floor heating or similar)	7 / 44.6	6 / 42.8	30 / 86	35 / 95
Application Rating Conditions	Outdoor Air	7 / 44.6	6 / 42.8	*	55 / 131

Source: Table 9, EN 14511-2—Air-to-water heat pumps - Heating mode. \* Test conducted at flow rate from standard rating conditions.

**Table 3: Federal Test Conditions—Heating Mode**

Test description	Air entering indoor unit temperature ( °F)		Air entering outdoor unit temperature ( °F)		Compressor speed	Heating air volume rate
	Dry bulb (DB)	Wet bulb (WB)	Dry bulb (DB)	Wet bulb (WB)		
H0,Test (required, steady)	70	60 <sup>(max)</sup>	62	56.5	Minimum	Heating Minimum.
H1 <sub>2</sub> Test (required, steady)	70	60 <sup>(max)</sup>	47	43	Maximum	Heating Full-Load.

Source: Table 12, 10 CFR 430, Subpart B, Appendix M —Heating Mode Test Conditions for Units Having a Variable-Speed Compressor.

Because the performance that is achieved for each model of the Altherma system is dependent on site specific design and installation and “balance of system” elements for the specific design, staff has proposed that a single calculated HSPF rating should be used to represent all models—HSPF 11.0, based on an average COP of 4.2.

**B. Space Cooling**

The DOE approved in the Daikin waiver the use of full load cooling test results. European Standard EN 14511 does not determine a space cooling SEER rating, only EER values. EER values consider the part load operational losses due to cycling of the compressor during conditions set by the test. The DOE test procedure for SEER also accounts for part load operational losses but instead of being evaluated at a single operating condition, it represents the expected overall performance for a typical year's weather. The DOE's SEER calculation assumes the same indoor temperature, but over a range of outside temperatures to deliver sufficient cooling energy.

To be comparable to the DOE's tested SEER value, Daikin proposed efficiency ratings specific to each of the nine models of the Altherma system based on their European testing results for comparable testing conditions of the DOE test. European and DOE cooling mode testing conditions are presented in Tables 4 and 5.

**Table 4: European Test Conditions—Cooling Mode**

		Outdoor Heat Exchanger		Indoor Heat Exchanger	
		Inlet Dry Bulb (DB) Temp (°C / °F)	Inlet Wet Bulb (WB) (°C / °F)	Inlet Temp (°C / °F)	Outlet Temp (°C / °F)
Standard Rating Conditions	Water	35 / 95	Na	12 / 53.6	7 / 44.6
	Water (floor cooling or similar)	35 / 95	Na	23 / 73.4	18 / 64.4
Application Rating Conditions	Water	27 / 80.6	Na	*	7 / 44.6
	Water (floor cooling or similar)	27 / 80.6	Na	*	18 / 64.4
	Water	46 / 114.8	Na	*	7 / 44.6

Source: Table 10, EN 14511-2 — Air-to-water heat pumps and liquid chilling packages - Cooling mode. \*Test conducted at flow rate from standard rating conditions.

**Table 5: Federal Test Conditions—Cooling Mode**

Test description	Air entering indoor unit temperature ( °F)		Air entering outdoor unit temperature ( °F)		Compressor speed	Cooling air volume rate
	Dry bulb (DB)	Wet bulb (WB)	Dry bulb (DB)	Wet bulb (WB)		
A <sub>2</sub> Test—required (steady, wet coil)	80	67	95	75	Maximum	Cooling Full-Load
B <sub>2</sub> Test—required (steady, wet coil)	80	67	82	65	Maximum	Cooling Full-Load
E <sub>v</sub> Test—required (steady, wet coil)	80	67	87	69	Intermediate	Cooling Intermediate
B <sub>1</sub> Test—required (steady, wet coil)	80	67	82	65	Minimum	Cooling Minimum
F <sub>1</sub> Test—required (steady, wet coil)	80	67	67	53.5	Minimum	Cooling Minimum

Source: Table 6, 10 CFR 430, Subpart B, Appendix M—Cooling Mode Test Condition for Units Having a Variable-Speed Compressor.

Daikin provided tested EERs for each Altherma model based on performance testing conditions that most closely match the testing temperature conditions used for the DOE’s SEER rating. These temperature and part load conditions are shown in Table 6.

**Table 6: Altherma Ambient Testing for SEER Rating**

Altherma Test Conditions based on EN 14511	Test Description	LWT	Ambient Temp °F	Compressor	
	A2 Alternate	64.4	95	Max	100%
B2 Alternate	64.4	80.6	Max	100%	
Ev Alternate	64.4	80.6	Max	50%	
B1 Alternate	64.4	80.6	Min	25%	
F1 Alternate	64.4	68	Min	25%	

Source: Daikin letter to California Energy Commission dated, January 6, 2011.

For each Altherma model, Daikin determined an EER for each test condition, which through further calculations was converted to SEER. Staff does not agree with this approach. European testing does not determine full load SEER values, and the system’s energy use is dependent on variations in the “balance of system” and control mechanisms that are specific to the actual site installation. Staff believes that a single cooling SEER efficiency rating that is consistent with the minimum cooling efficiency required by the federal Appliance Standards should be used to represent all Daikin Altherma models —SEER 13.0.

C. Water Heating

European Standard EN 14511 is performed at a standard rating point and several application rating conditions. The energy calculation for systems that provide space

conditioning and domestic hot water accounts for each sub-system, and its system thermal loss is calculated and added to its heat output to determine its required heat input for the test. The COP resulting from the European test accounts for any sub-system (i.e., domestic water heating) that is an integrated part of the system. Any auxiliary energy that is attributed to the test conditions contributes to the energy losses of the sub-system.

The DOE testing procedures don't apply to systems with integrated space conditioning and water heater functions (75 Fed. Reg. 117). To bridge this testing difference, Daikin proposed efficiency ratings specific to each of the nine models of the Altherma system based on standard rating conditions that are comparable to the DOE test for a heat pump water heater (Table 7).

**Table 7: Test Conditions for Water Heating Energy**

Scope		DOE Test Condition	Altherma Test Condition
Test Conditions	Installation	Installed per Section 4 of test	Installed at outdoor ambient
	Ambient Temp	67.5 F	44.6. F
	Supply Water Temp	58 F	50 F
	Storage Tank Temp	135 F	131 F
	Supply Water Pressure	Between 40 psi and max allowed by manufacturer	Same

Source: Daikin letter to California Energy Commission dated, January 6, 2011.

The COP rating was derived from the European test for each Altherma model based on the test condition having a LWT of 131 F, and was converted to an EF rating to represent the index value required for showing performance compliance with the Standards. Staff notes that while the European test may account for sub-system energy effects, a single performance rating representing the average water heating performance rating for all models is more appropriate—EF 2.4.

2. *For compliance purposes, the Daikin Altherma system's water heating efficiency should only be based on federal test procedure testing of the equipment as a heat pump water heater. The water heating efficiency of the system should not be allowed to be based on the operation of the system as a combined hydronic system.*

Combined hydronic systems use a single heat source to provide both space conditioning and water heating. The Daikin Altherma system is designed to operate as a combined hydronic system, providing both space conditioning and water heating in an integrated manner. In the European test, heat pumps with a combined space heating and domestic hot water function have two kinds of operation modes accounted for: alternate and simultaneous operation. In alternate operation, the heat pump switches from the space heating system to the domestic hot water system when there is a domestic hot water demand.

The Daikin Altherma system has design and control mechanisms within the system that limit its operation such that it provides energy for space heating, or space cooling, and water heating in an efficient manner, meeting the demand for each function sequentially. The DOE in its waiver approval has authorized the European test procedure to be used to represent the Altherma system's efficiency while serving space heating, space cooling, and its water heating function. Therefore, for showing performance compliance with the Standards, it's appropriate that all modeling software input values that represent the design functions of the Altherma system be allowed to be used, dependent on the specific design.

4. *Is there allowance to use the proposed efficiency ratings for the Daikin Altherma system to other split-system heat pumps offered in the marketplace?*

Staff proposed efficiency ratings for the Daikin Altherma system are based on two critical considerations: (1) the DOE's express granting of a waiver solely for the Daikin Altherma system from meeting federal test procedures and authorization to use European equipment testing results for the Altherma system, and (2) Daikin's submission to the Energy Commission of an application for compliance option supported by specific European test procedure results that were expressly authorized by the DOE waiver.

Performance ratings for space conditioning and water heating equipment are specific to the manufacturer's equipment or system. Space conditioning and water heating equipment used to show compliance with the Standards must meet federally mandated efficiency levels and testing procedures. Equipment performance ratings from federal testing are used in Energy Commission performance modeling software to demonstrate compliance with the Standards. Performance values from testing are uniquely authorized for use for the individual manufacturer's equipment.

Manufacturers of equipment who do not have testing results based on federal procedures would have to demonstrate to the Energy Commission that:

- A DOE waiver from meeting federal test procedures has been granted
- The manufacturer's equipment has tested performance efficiency ratings meeting testing conditions set by the DOE waiver
- A request is made to the Commission to allow the use of efficiency ratings based on the DOE's authorized testing procedures for the specific equipment, supported by the test results from that authorized test procedure

5. *Is there a time limit to the Energy Commission's approval of efficiency ratings for the Daikin Altherma system?*

Staff recommended efficiency ratings for the Altherma system are to be used for showing performance compliance with the 2008 Residential Standards. Should the Energy

Commission approve staff recommended performance efficiency ratings, approved ratings would be subject to all DOE conditions of the waiver for this system.

The Appliance Efficiency Standards, Title 20, Section 1603(c) require that when systems have a waiver of the federal test method, which establishes a condition of adherence to an alternate test procedure, that the alternate test procedure is the test method that must be used for determining the system’s efficiency. Use of staff proposed efficiency ratings for the Daikin Altherma system are subject only to possible changes in the DOE’s conditions for granting the waiver, or changes in European Standard EN 14511, which could result in different testing results for the Altherma system.

## Proposed Compliance Option

The Daikin Altherma system can operate in multiple modes. Staff recommends that the Altherma system be described for compliance purposes as either:

- Split System Heat Pump, or
- Combined Hydronic system

Based on Daikin European appliance test results for the Altherma system, staff proposes the equipment efficiency ratings specified below to be used for all of the Altherma system models listed in Table 1:

<i>Space Heating</i>	HSPF – 11 (split system heat pump) EF – 2.4 (combined hydronic)
<i>Space Cooling</i>	SEER – 13
<i>Water Heating</i>	EF – 2.4*

\*When a separate stand alone water heater is used to provide water heating, the EF for that separate water heater shall be used for performance standards compliance.

Attachment A to this document contains staff’s proposed notification to building departments and the building industry of new efficiency ratings approved for the Altherma Air-to-Water Source Heat Pump system should the Energy Commission approve this compliance option. This document, *Efficiency Inputs for the Daikin AC (Americas), Inc. Altherma Air-to-Water Source Heat Pump System*, also specifies necessary modeling inputs to be used when demonstrating compliance using the performance approach for residential buildings.

## Conclusion

Staff believes the Daikin request and application for a compliance option is warranted, and the submitted information supporting the Altherma system and its various installed configurations is appropriate for the purpose of the request. All compliance information necessary to implement the proposed efficiency ratings for the Altherma system are included in Attachment A to this report.

The proposed efficiency ratings for the Altherma system provide a conservative estimate of the system's performance while allowing design flexibility in the field to meet specific installation needs at the building site. Staff recommends that the Energy Commission approve this compliance option. The compliance option is comprised of proposed efficiency ratings and installation criteria for the Altherma Air-to-Water Source Heat Pump system specified in this Final Evaluation Report.